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ELEVENTH MONTHLY PROGRESS REPORT ON DEVELOPMENT AND TESTING OF ELECTROLYTE MATRIX COMBINATIONS FOR MERCURY-POTASSIUM FUEL CELL

Eleventh monthly Progress Report (12 October–12 November 1963)

OTS

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FOREWORD

This is the final monthly progress report for contract NASw-476. All earlier monthly progress reports have been prepared to reflect the actual problems and the resulting delays in the program. The original program schedule was thought to be a realistic estimate of the program work, by tasks, which would assure success.

A review showed that delays in the third month caused a rescheduling in the fourth month. Further problems with the composite material in the fifth month resulted in a "Critical Review" of the methods for the preparation of the material. Only during the eighth month was a new estimate of work possible.

The new program called for exclusive attention to a fine grain composite. Work was to be done on the preparation and testing of small cell matrices, while a development program was underway for the preparation of larger disks for use in large (3-in. dia) cells. This effort resulted in the running of three cells with good, although limited, performances during the ninth month. Success here was attributed to the change in the MgO material from a light calcined product to an electronic grade MgO, thought to be a fused material.

Subsequent work was directed toward making changes in cell testing techniques while using the state-of-art composites. Two small cells were operated during the tenth month by the use of an amalgam for the anode in place of the more active K-metal. These cells operated for 32 hr and 18 1/2 hr at electrical performances corresponding to a performance factor ($\gamma\, t_e$) of 2 ohm-cm^2 or resistivity (γ) of 6 ohm-cm.

Ten small cell tests were performed prior to an attempt at the fabrication and testing of large cells. Work during the eleventh month included the testing of three large cells. This essentially completed the requirements for cell testing and is reported in the following paragraphs.

PROGRESS OF WORK DURING THIS REPORTING PERIOD

The progress this month includes some final conductivity test data plus the performance data from the three 3-in. diameter cells.

CONDUCTIVITY TEST RESULTS

Work with conductivity specimens has been done only as new material is prepared. Standard procedure has been to fabricate three such specimens from each batch. In some cases where a batch was ruled out by other considerations, the conductivity work was not completed. Tables I and II complete the compilation of all conductivity data for the present program.

CELL TESTING

Two large (3-in. dia) cells were operated during the reporting period. The cell using the concentric serrated seal was operated twice. Another configuration, which incorporated a smooth surface seal, was operated in a horizontal position much like that of a differential density cell. Therefore, the two configurations tested give a broad range of conditions for the 3-in. dia cells. Table III is a tabulation of data of these three tests.

NASA-XIII

The first large cell was designated NASA-XIII. The cell was fabricated using a 4-in. x 1/8-in. composite matrix with 65% electrolyte content and 82.2% of theoretical density. This configuration, shown in Figure 1, has an inherent disadvantage in a gravity field. Any residual gas, driven from the Hg upon heating, is collected in the region under the matrix and causes high resistance performance. In a true differential density cell, this gas film is relieved by passing through the liquid electrolyte.

The NASA-XIII cell operated 4 hr with 15 charge-discharge cycles. The apparent resistivity of 40 ohm-cm computed from voltage-current figures includes the gas film resistance and any other lead resistances that were present. The posttest analysis of the matrix showed that a pressure from amalgam buildup caused the matrix to rupture.

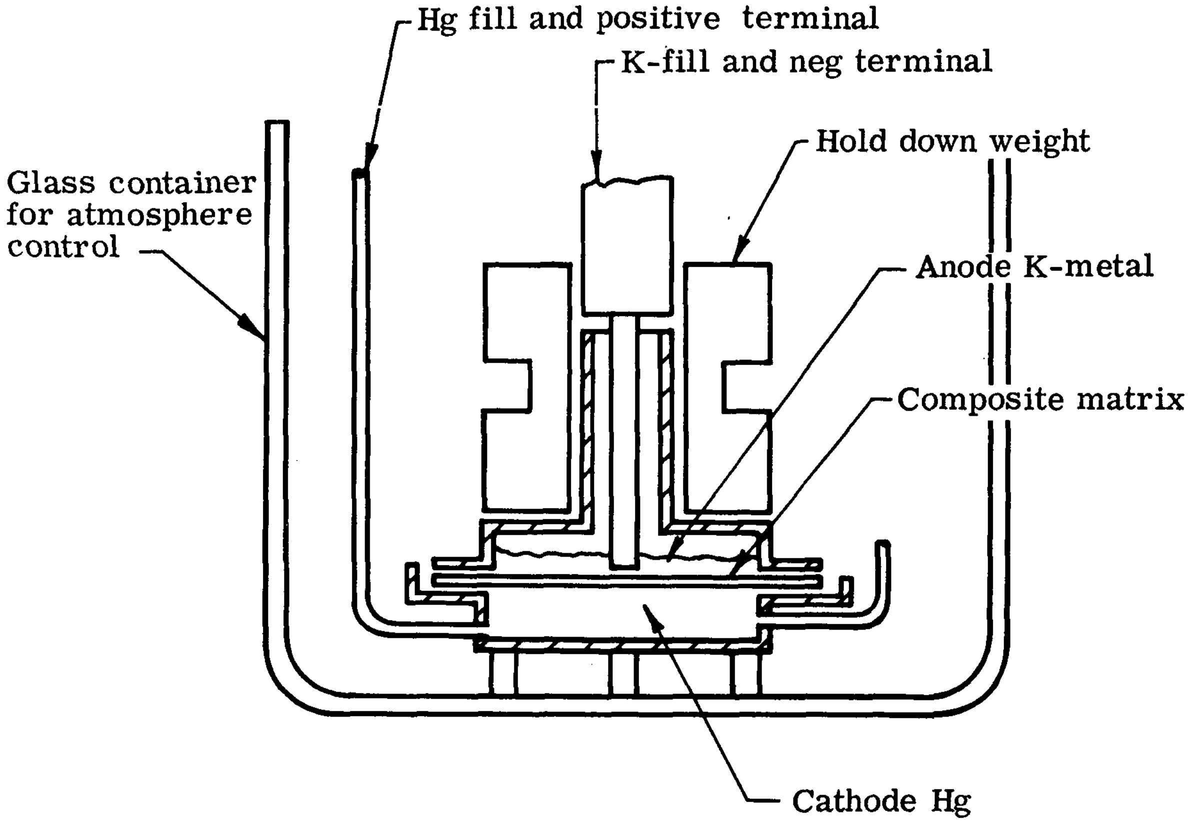

Figure 1. Schematic of liquid metal cell NASA XIII.

The data (Table III) are presented to describe each cycle and reflect the gradual change in the internal resistance prior to failure. The values given for V_o are indicative of the change in cell potential between charge and discharge operation, but were taken prior to the time required for full recovery.

NASA-XI

The design of this cell followed closely that of the small cell which was used for 10 tests during the program. Figure 2 is a photo of the cell showing the salient features. These data are included in Table III.

This cell gave good performance for 3.2 hr before serious shorting caused a lower resistance and lower cell potential. The total electrical performance existed for 5.2 hr. The matrix survived at cell operating temperature for 17 hr.

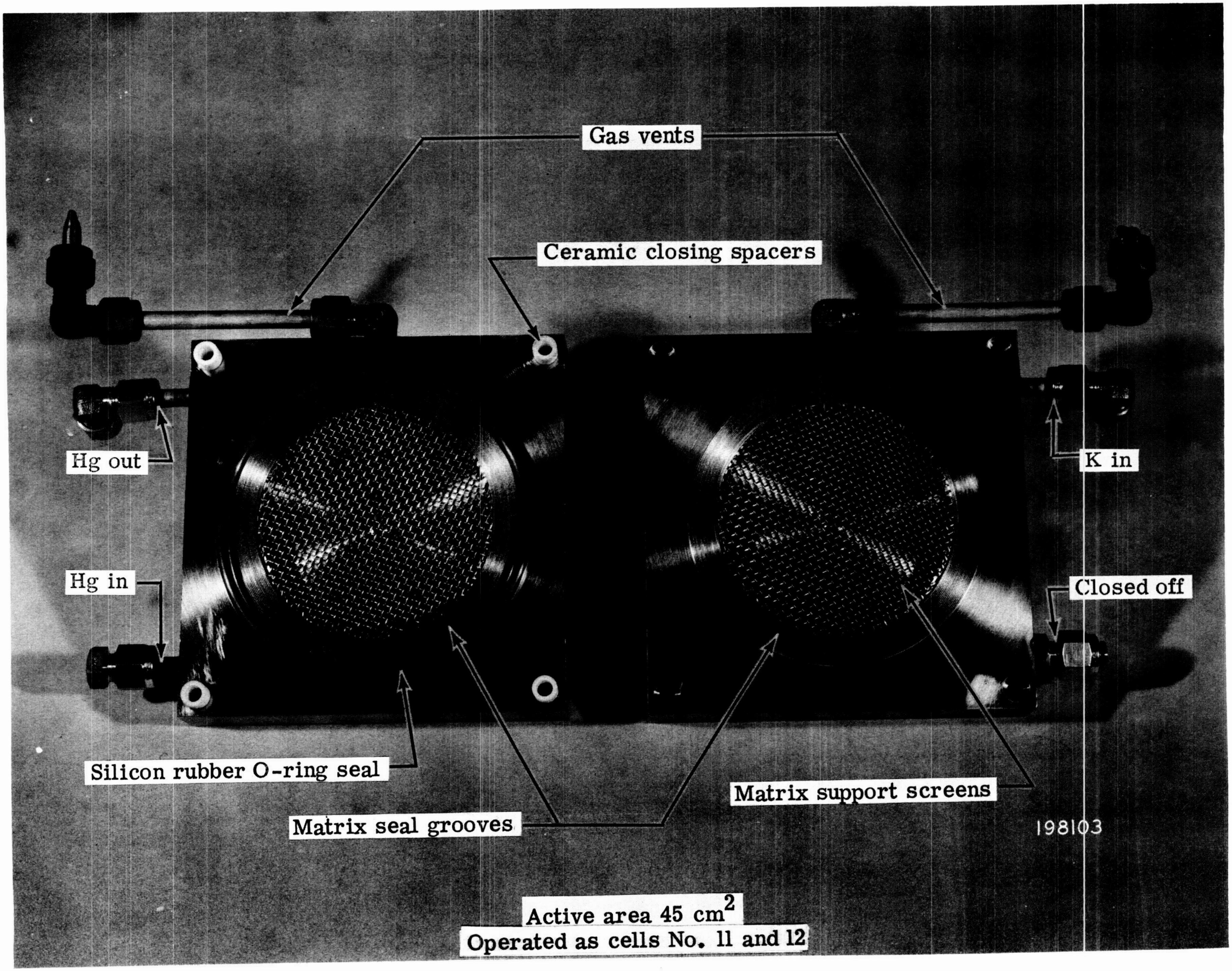

Figure 2. NASA paste matrix cell.

An oversight in instrumentation hookup caused an error in voltage measurement. The voltage leads were placed on the current carrying terminals. This caused a higher resistance to be indicated across the cell. A posttest investigation, using a brass plate in place of the matrix, showed the extra resistance (Δ R) to be 0.049 ohm.

The resistivity values shown in Table III are corrected for this constant. Cause of failure was found to be a crack which developed in the seal region near the active cell area.

NASA-XII

This cell was fabricated using another 65% electrolyte content matrix. Total operating time was 82 hr. The performance of this cell indicated a resistivity of 10-12 ohm-cm. Cause of this higher resistance has not been determined. The loss in cell effective area due to the screens has been suggested as a source of extra resistance. However, cells IX, X, and XI also had screens of the same material and show lower resistance. Other factors such as differences in conductivity of batches, concentration buildup within the screen pockets, or interfacial resistance caused by screens are to be considered before the final report is completed.

This preliminary data shows performance which is below that desired, namely a performance factor of $\gamma t_e = 1.0$ ohm-cm^2 for the 1/8-in. matrix or a resistivity of $\gamma = 3.0$ ohm-cm. However, the development of matrix and cell combinations which should match these goals is now seen to be possible. Extension of work will be done in another phase, since the goals of the contract have been met with the proof of feasibility demonstrated by these tests.

FUTURE WORK

Because this is the last period of the contract performance time, the remaining effort will be directed toward the analysis of all data and the forming of a Final Report.

CUMULATIVE MAN MONTHS EXPENDED

	Through 12 November
Research	26.4
Shop	0.8
Materials Laboratory	20.2
Total	47.4
Budget	
Research	30
Shop	2
Materials Laboratory	17

Table I.

Conductivity specimen identification.

Specimen No.	Nominal Weight Ratio	Percent of Theoretical Density	Diameter (in.)	Height (in.)	Test Height (in.)
45	63/37	89.2	0.606	0.691	0.600
46	63/37	88.1	0.607	0.690	0.600
47	63/37	88.5	0.607	0.692	0.600
48	34/66	82.4	0.608	0.648	0.600
49	34/66	82.1	0.610	0.648	0.600
50	34/66	81.4	0.609	0.649	0.642*
51	34/66	84.6	0.614	0.613	0.580
52	34/66	83.6	0.614	0.618	0.580
53	34/66	84.6	0.614	0.612	0.580
54	33/67	84.0	0.612	0.577	0.580
55	33/67	84.6	0.607	0.595	0.580
56	33/67	81.1	0.628	0.589	0.580
57	50/50	87.5	0.621	0.588	0.580
58	50/50	87.5	0.623	0.648	0.600
59	50/50	87.8	0.617	0.676	0.600
60	60/40	89.9	0.618	0.635	0.600
61	60/40	90.2	0.618	0.622	0.600
62	60/40	89.2	0.620	0.635	0.600
63	65/35	84.7	0.622	0.728	0.607
64	65/35	85.0	0.622	0.744	0.600
65	65/35	85.1	0.625	0.718	0.602

*Measured after test—all others nominal mechanical stop value

Table II.

Conductivity specimen data.

Specimen No.	Temperature (°K)	Conductance (Mho)	Conductivity (Mho/cm)	$\frac{1}{T} \times 10^3 (°K)^{-1}$
45	619	0.282	0.231	1.62
	595	0.227	0.186	1.68
	569	0.173	0.142	1.76
	546	0.119	0.097	1.83
	522	0.027	0.022	1.92
46	599	0.2765	0.226	1.67
	626	0.3472	0.284	1.60
	603	0.2859	0.234	1.66
	564	0.1786	0.146	1.77
	548	0.1406	0.115	1.82
	527	0.0940	0.077	1.90
47	566	0.1867	0.152	1.77
	594	0.2688	0.220	1.68
	625	0.3452	0.282	1.60
	606	0.2960	0.242	1.65
	573	0.2248	0.184	1.74
	552	0.1734	0.142	1.81
	529	0.1234	0.101	1.89
48	566	0.0435	0.036	1.77
	595	0.0643	0.053	1.68
	628	0.0928	0.076	1.59
	591	0.0580	0.048	1.69
	572	0.0458	0.038	1.75
	545	0.0071	0.006	1.83
Questionable data	513	?	0.0002	1.95
49	Contact with specimen not attained.			
50	567	0.0423	0.037	1.76
	598	0.0589	0.051	1.67
	625	0.0777	0.068	1.60
	592	0.0518	0.045	1.69
	569	0.0366	0.032	1.76
	547	0.0190	0.016	1.83
	529	0.005	0.004	1.89
51	576	0.0405	0.031	1.73
	609	0.062	0.048	1.64
	618	0.075	0.058	1.62
	628	0.078	0.060	1.59
	608	0.062	0.048	1.64
	572	0.037	0.028	1.75
	545	0.007	0.005	1.83
	524	0.0005	(0.0004)	1.91

Table II. (Cont)

Specimen No.	Temperature (°K)	Conductance (Mho)	Conductivity (Mho/cm)	$\frac{1}{T} \times 10^3 (°K)^{-1}$
52	569	0.027	0.021	1.76
	601	0.055	0.042	1.66
	621	0.078	0.060	1.61
	598	0.057	0.044	1.67
	570	0.039	0.030	1.75
	550	0.023	0.018	1.82
	518	0.002	0.002	1.93
53	574	0.041	0.032	1.74
	591	0.052	0.040	1.69
	626	0.079	0.061	1.60
	596	0.053	0.041	1.68
	572	0.038	0.029	1.75
	545	0.012	0.009	1.83
	520	0.001	0.0008	1.92
54	Contact with specimen not attained.			
55	572	0.0611	0.048	1.75
	619	0.108	0.085	1.62
	592	0.080	0.063	1.69
	573	0.0616	0.049	1.74
	549	0.0388	0.031	1.82
	524	0.0118	0.009	1.91
56	574	0.0966	0.071	1.74
	601	0.1293	0.095	1.66
	653	0.1836	0.135	1.53
	622	0.1432	0.105	1.61
	598	0.1176	0.087	1.67
	573	0.0930	0.068	1.74
	548	0.0657	0.048	1.82
	524	0.0450	0.033	1.91
57	587	0.0860	0.065	1.70
	603	0.1170	0.088	1.66
	628	0.1715	0.129	1.59
	603	0.1380	0.104	1.66
	578	0.1030	0.078	1.73
	553	0.0729	0.055	1.81
	529		0.023	1.89
58	598	0.1540	0.119	1.67
	620	0.2059	0.159	1.61
	589	0.1325	0.118	1.70
	571	0.1171	0.091	1.75
	547	0.0866	0.067	1.83
	514	0.0370	0.029	1.95

Table II. (Cont)

Specimen No.	Temperature (°K)	Conductance (Mho)	Conductivity (Mho/cm)	$\frac{1}{T} \times 10^3 (°K)^{-1}$
59	571	0.0931	0.078	1.75
	606	0.1580	0.133	1.65
	631	0.1850	0.156	1.59
	588	0.1053	0.089	1.70
	565	0.0782	0.066	1.77
	544	0.0561	0.047	1.84
	503	0.0103	0.009	1.99
60	565	0.1489	0.117	1.77
	595	0.2151	0.169	1.68
	625	0.3083	0.243	1.60
	597	0.2293	0.180	1.68
	561	0.1226	0.096	1.78
	534	0.0577	0.045	1.87
	516	0.0154	0.012	1.94
61	566	0.1487	0.117	1.77
	596	0.2218	0.174	1.68
	626	0.3056	0.240	1.60
	603	0.2474	0.195	1.66
	579	0.1722	0.136	1.73
	547	0.1058	0.083	1.83
	524	0.0605	0.048	1.91
62	568	0.1776	0.139	1.76
	600	0.2568	0.201	1.67
	629	0.332	0.260	1.59
	597	0.2532	0.198	1.68
	570	0.1645	0.129	1.75
	549	0.1165	0.091	1.82
	521	0.0830	0.065	1.92
63	558	0.3523	0.33	1.79
	561	0.3625	0.34	1.78
	564	0.3750	0.35	1.77
	570	0.3958	0.37	1.75
	578	0.4243	0.40	1.73
	587	0.4536	0.43	1.70
	596	0.4798	0.45	1.68
	605	0.510	0.48	1.65
	614	0.5346	0.50	1.63
	578	0.4080	0.38	1.73
	561	0.3430	0.32	1.78
64	548	0.3745	0.291	1.83
	563	0.4243	0.33	1.78
	573	0.4594	0.357	1.75
	583	0.5069	0.394	1.72
	598	0.5422	0.422	1.67

Table II. (Cont)

Specimen No.	Temperature (°K)	Conductance (Mho)	Conductivity (Mho/cm)	$\frac{1}{T} \times 10^3 (°K)^{-1}$
65	525	0.192	0.153	1.90
	553	0.278	0.221	1.81
	596	0.407	0.325	1.68
	573	0.351	0.251	1.75
	626	0.4682	0.373	1.60
	668	0.5882	0.469	1.50
	571	0.3085	0.246	1.75
	556	0.2180	0.174	1.80
	528	0.1282	0.0922	1.89
	527	0.1175	0.0936	1.90

Table III.

Data on composite electrolyte matrix cells.

Cell electrolyte percentage, and date	Time of day	Open circuit potential V_o	Operating potential V_o*	Operating voltage V_c	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
NASA-XIII	Cycle No. 1	0.93	0.86	0.42	1.0	0.44	59
65%	(1:25 PM)	1.08	1.12	1.37	(regulated)	0.25	
10-24-63	2	0.975	0.91	0.61		0.30	40
		1.10	1.13	1.40		0.27	
	3	0.97	0.90	0.59		0.31	42
		1.095	1.12	1.395		0.275	
	4	0.98	0.92	0.62		0.30	40
		1.09	1.12	1.385		0.265	
	5	0.98	0.92	0.63		0.29	39
		1.09	1.12	1.36		0.24	
	6	0.985	0.93	0.64		0.29	39
		1.075	1.12	1.36		0.24	
		(Began unstable operation with intermittent shorts.)					
	7	0.985	0.935	0.67		0.265	36
		1.06	1.11	1.34		0.23	
	8	0.98	0.935	0.655		0.28	38
		1.06	1.10	1.33		0.23	
	9	0.98	0.94	0.675		0.265	36
		1.05	1.09	1.30		0.21	
	10	0.98	0.94	0.695		0.245	33
		1.02	1.07	1.28		0.21	
	11	0.975	0.93	0.67		0.26	35
		0.98	1.015	1.23		0.215	
	12	0.965	0.92	0.685		0.235	31
		1.01	1.035	1.26		0.225	
	13	0.91	0.86	0.605		0.255	34
		0.97	1.02	1.24		0.22	
	14	0.94	0.86	0.62		0.24	32
		0.95	1.01	1.225		0.215	
		(Highly unstable—readings average)					
	(5:36 PM) 15	0.89	?	0.62		—	
		0.89	0.96	1.17		0.21	
		(Major breakdown—cell dead)					
NASA-XI	1:30 PM	(Cell fabricated—start heat-up)					
65%	8:00	(Cell at 300°C—tighten clamp)					
10-28-63							
10-29-63	7:50 AM					~9.0 (measured)	
	8:45	(Hg loaded to preheater)					
	9:15	0.0	—	0.35	0.1	3.5 (resistance test)	
	9:28	(Start Hg loading)					
	10:05	(Hg full)				~1.0 (measured)	
	10:15	(Start amalgam heat-up)					
	10:21	0.50	(amalgam loading)				
	10:21:12	0.75					
	10:21:24	0.85					
	10:22	0.93					
	10:23	0.98					
	10:24	1.00					
	10:41			0.51	2.6		
	10:45		0.79	0.51	2.6	$\frac{0.108}{0.059}$	8.1

Table III. (Cont)

Cell electrolyte percentage, and date	Time of day	Open circuit potential V_o	Operating potential V_o*	Operating voltage V_c	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
	10:46	0.88					
	10:58	(Start charge-discharge cycling)					
	Cycle No. 1			0.985	1.0		
		0.84		0.485	2.6		
	5			0.975	1.0		
		0.83		0.48	2.6		
	10			0.965	1.0		
		0.82		0.48	2.6		
	11:33		0.76	0.475	2.6	$\frac{0.11}{0.061}$	8.4
	14			0.955	1.0		
		0.81		0.47	2.6		
		(Slight internal short indicated)					
	11:41		0.73	0.41	3.0	$\frac{0.107}{0.058}$	8.0
	15			0.935	0.95		
		0.805		0.46	2.55		
	20			0.915	1.0		
		0.78		0.44	2.6		
	25			0.895	1.05		
		0.76		0.40	2.6		
	30			0.885	1.05		
		0.75	0.67	0.40	2.6	$\frac{0.104}{0.055}$	7.6
	1:26	(Frequent shorting—cycler turned off)					
	1:29			0.50	1.7		
	1:32			0.15	0.5		
	1:33			0.06	0.3		
	1:42		0.05	0.17	2.2	$\frac{0.055}{0.006}$	0.8
	1:53	(Unexplained recovery)					
	1:56			0.76	1.25		
	1:57	0.15	(Internal shorting)				
	1:58		0.105	0.25	2.05	$\frac{0.071}{0.022}$	3.0
	2:22		0.07	0.22	2.1	$\frac{0.071}{0.022}$	3.0
	2:32		0.07	0.49	6.1	$\frac{0.069}{0.020}$	2.8
	3:32		0.02				
		(Shutdown)					
		Posttest lead resistance study					
		0.0		0.49	10.0	0.049	
		0.0		0.05	1.0	0.05	
NASA XII	10:00 AM	(Cell fabricated—start heat-up)					
65%	4:45 PM	(Cell at 300°C—tighten clamp)					
11-7-63							
11-8-63	8:45 AM	(Cell rotated to vertical position)					
	9:17	(Add Hg to preheater)					
	9:56	(Start amalgam heat-up)					
	10:02	(Start Hg fill)					
	10:14	(Hg filled)					
	10:19	0.50	(Amalgam loading)				

Table III. (Cont)

Cell electrolyte percentage, and date	Time of day	Open circuit potential V_o	Operating potential V_o^*	Operating voltage V_c	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
	10:19:12	0.67					
	10:19:24	0.70					
	10:20	0.70					
	10:21	0.85					
	10:22	0.91					
	10:24	0.95					
	10:30	1.04					
	10:34	(Start cycling)					
	10:38		0.80	0.53	3.35	0.081	11.2
	10:43		0.80	0.58	3.00	0.073	10.1
	11:26		0.68	0.17	6.8	0.075	10.4
	1:21		0.75	0.52	2.33	0.099	13.7
	Cycle No. 40			0.59	1.95		
		0.83		1.15	1.95		
	2:26		0.77	0.60	1.95	0.087	12.0
	3:11 50			0.60	1.95		
		0.83		1.18	1.95		
	4:04 60		0.76	0.59	1.95	0.087	12.0
		0.825		1.225	1.95		
	4:30		0.67	0.27	3.60	0.111	15.3
	5:07	Maximum power investigation				P watts (1)	
	Cycle No. 63	0.80		0.74	0.60	0.445	
	68			0.73	0.65	0.474	
	70			0.725	0.70	0.506	
	72			0.71	0.825	0.585	
	73			0.67	1.10	0.736	
	76			0.66	1.20	0.790	
	77			0.65	1.30	0.846	
	79			0.635	1.42	0.90	
	80			0.63	1.52	0.945	
	81			0.62	1.60	0.99	
	82			0.56	2.0	1.12	
	84			0.455	2.8	1.27	
	100	(brought forward)		0.360	3.8	1.37	
	8:37		0.67	0.26	3.8	0.108	14.9
	10:07		0.75	0.66	1.0	0.090	12.4
	Cycle No. 150			0.66	1.0		
		0.805		0.965	1.0		
11-9-63	200			0.645	1.0		
		0.80		0.965	1.0		
	213			0.62	1.0		
		0.775		0.775	1.0		
	7:08 AM 215	(indication of internal short ΔV = 0.02 volts)					
	10:08 249	(indication of internal short ΔV = 0.04 volts)					
	250			0.58	1.0		
		0.75		0.895	1.0		
	264			0.58	1.0		
		0.74		0.875	1.0		
	11:31		0.68	0.58	1.0	0.10	13.8
	11:38		0.51	0.285	2.63	0.086	11.7
	11:56	(on charge)		0.90	0.55		
	1:10	0.73					

(1) Figures in this column, between the lines above and below, record power values. Balance of the column are resistance figures.

Table III. (Cont)

Cell electrolyte percentage, and date	Time of day	Open circuit potential V_o	Operating potential V_o*	Operating voltage V_c	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
	1:14	(on charge)		1.06	1.05		
	1:28	0.82					
	Cycle No. 267	(Change cycle ratio for longer charge time 150 sec change—30 sec open circuit—115 sec discharge—30 sec open circuit)					
	No. 273			0.59	0.6		
		0.725		0.85	0.6		
	2:26	(on charge)		1.05	1.0		
	2:49	(off charge—on cycling)					
	3:18 No. 280			0.59	0.7		
		0.815		1.07	0.7		
	4:18 No. 289			0.56	0.75		
		0.805		1.05	0.75		
	No. 300			0.50	0.75		
		0.73		0.97	0.75		
	(Frequent internal shorting—stop cycling on No. 331)						
		0.61					
	8:11	(on charge)		0.765	0.70		
	8:46			1.25	2.68		
	9:06	0.80					
	9:16	(Start cycling)					
	No. 333			0.50	0.55		
		0.56		0.64	0.55		
	No. 339			0.195	0.55		
		0.26		0.335	0.55		
	No. 370			0.11	0.58		
		0.195		0.27	0.58		
	No. 401			0.04	0.58		
		0.15		0.26	0.58		
	No. 425			0.00	0.55		
		0.11		0.22	0.55		
	Power supply driving cell neg from No. 425 to No. 450						
11-10-63	7:55 No. 450			Neg	0.55		
		0.12		0.245	0.55		
	8:15		0.185	0.245	0.55	0.109	15.0
	8:15		0.11	0.16	0.55	0.091	12.6
	9:02	0.08	(Left on open circuit overnight)				
11-11-63	8.05 AM	0.032					
	9:07	0.035					
	9:46	(on charge)		0.13	0.55		
	10:17		0.10	0.165	0.55	0.118	16.3
	10:30	0.05					
		(Indicates anode is K-metal deficient)					
	11:18	(Placed total of 10 grams K-metal in loader)					
	11:19	0.10					
	11:20	0.20					
	11:21	0.25					
	11:26		0.160	0.105	0.80	0.069	9.5
	11:27	0.23					
	11:29	(on charge)		0.35	1.10		
	11:57	0.24					
	12:05	0.26					
	12:06	0.08					

Table III. (Cont)

Cell electrolyte percentage, and date	Time of day	Open circuit potential V_o	Operating potential V_o*	Operating voltage V_c	Load current, I (amp)	Computed cell resistance R (ohms)	Resistivity γ (ohm-cm)
	12:11	(on charge)		0.14	1.10		
	12:14	(Flushed cathode with 30 cc Hg)					
	12:15		0.075	0.12	1.10	0.041	5.7
	1:36		0.085	0.13	0.85	0.053	7.3
	1:50	0.06	(5 gram K-metal loaded)				
	1:55	0.08					
		(On open circuit to make ac bridge measurements)					
	2:28	Frequency 10^4 cps—R = 0.088 - 0.041 = 0.047 ohm					
		Frequency 10^3 cps—R = 0.088 - 0.041 = 0.047 ohm					
	2:36	0.07					
	2:49	(on charge)		0.165	1.0		
		(Start cell heat-up from 300°C)					
	3:27		0.11	0.16	1.0	0.05	6.9
	3:45			0.46	1.0	(Temperature at 320°C)	
	3:49	(Start cycling with No. 452)					
	Cycle No. 455			0.25	1.35		
		0.375		0.48	1.35		
			0.29	0.25	1.35	0.03	4.1
	4:19 No. 457	Stop cycling		0.46	1.35		
	4:24	(Flushed cathode with 30 cc Hg)					
	4:33		0.07	0.085	1.35	~0.011	1.5
	4:38	0.045					
	5:00	0.03	(Place on charge)		1.35		
	5:57	(charge)		0.085	2.0		
	6:30	(charge)		0.125	3.05		
	6:53		0.10	0.17	3.05	0.023	3.2
	7:00			0.185	3.1		
	7:03			0.23	3.1		
	7:04			0.42	3.1		
	7:05			0.46	3.1		
	7:06			0.465	3.1		
	7:07			0.36	1.0		
	7:09	(Start cycling with No. 458)					
	No. 459			0.232	1.0		
		0.29		0.345	1.0		
			$\Delta V \simeq 0.02$		1.0	> 0.02	~2.8
	8:18 No. 470			0.242	1.0		
		0.295		0.35	1.0		
		Indicates a low resistance cell					
11-11-63	8:19 PM	Shutdown operation					